PATENT ABSTRACTS OF JAPAN

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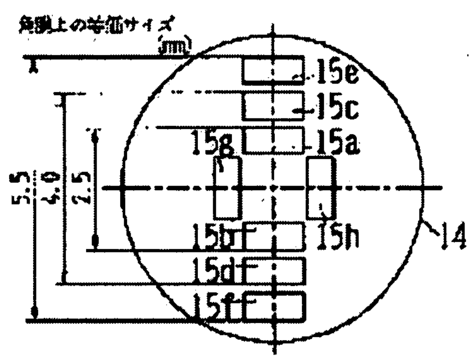
(54) OPHTHALMOLOGIC MEASURING DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To measure eye refracting power in a plurality of different cornea portions by providing the device with a slit projection optical system for scanning an eye bottom to be inspected and a detection optical system having plural pairs of light receiving elements disposed symmetrically to an optical axis and calculating the refractive power of the inspected eye based on the phase difference signal output of each light receiving element.



SOLUTION: For measuring eye refracting power, first the cornea center of a ruled line direction where light receiving elements 15a to 15f are positioned are obtained from the outputs of light receiving elements 15g and 15h in a light receiving part 14, and then refracting power in cornea portions corresponding to the respective light receiving elements 15a to 15f is obtained for the center. That is, slit luminous fluxes by a slit projection optical system are scanned and signal output wave forms are obtained when slit images reflected from the eye bottom cross the respective light receiving elements 15a, 15b, 15g and 15h. Then, from the light voltage signals of the light receiving elements 15g and 15h positioned in a direction orthogonal to the light receiving elements 15a and 15b, a center between the light receiving elements 15a and 15b is obtained and a time difference between the cornea equivalent positions of the light receiving elements 15a and 15b is obtained and thereby refracting power in each cornea portion is obtained.

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CLAIMS

[Claim(s)]
[Claim 1] The slit projection optics which scans eyegrounds examined the eyes in the slit flux of light in the ophthalmology measuring device which measures the refractive power examined the eyes, the direction of circles of longitude corresponding to the direction of a slit of this slit flux of light -- and the cornea examined the eyes and abbreviation -- with detection optical system with two or more pairs of photo detectors arranged on both sides of an optical axis in a location [****] at the symmetry The ophthalmology measuring device characterized by having a refractive-power operation means to acquire the refractive power examined [which changes in the direction of circles of longitude based on each phase contrast signal output of said photo detector] the eyes.
[Claim 2] It is the ophthalmology measuring device which the ophthalmology measuring device of claim 1 has a rotation means rotate the slit flux of light further projected by said projection optics and the photo detector with which said detection optical system is equipped synchronizing with the circumference of an optical axis, respectively, and the control means which drives this rotation means at a predetermined include-angle step, and is characterized by for said refractive-power operation means to acquire distribution of eye refractive power in quest of the refractive power in two or more cornea parts for a majority of every directions of circles of longitude.
[Claim 3] The ophthalmology measuring device of claim 2 is an ophthalmology measuring device characterized by having a display means to display distribution of refractive power further.
[Claim 4] The display means of claim 3 is an ophthalmology measuring device characterized by being the means which carries out a graphic display.
[Claim 5] the direction of circles of longitude in which the ophthalmology measuring device of claim 1 does not correspond in the direction of a slit of the slit flux of light by said projection optics further -- and the reflected light from eyegrounds examined the eyes -- the cornea examined the eyes and abbreviation -- on both sides of an optical axis, it is arranged in a location [****] at the symmetry -- with the 2nd photo detector of a pair at least this -- with a main detection means to detect a cornea core or a visual-axis core based on the phase contrast signal output between the 2nd photo detector

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the ophthalmology measuring device which measures the refractive power examined the eyes.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] When correcting the ametropy examined the eyes with a spectacle lens or a contact lens, the subjective examination for determining the formula value is conducted. On the occasion of a subjective examination, the method of using the measurement data of the eye refractive-power measuring device which measures the refractive power examined the eyes in other ** has spread widely. the light which scans the slit-like flux of light, projects on eyegrounds examined the eyes as an eye refractive-power measuring device, and is reflected by projection of the slit flux of light from eyegrounds examined the eyes -- the cornea examined the eyes and abbreviation -- what acquires the refractive power examined the eyes based on detecting by two pairs of photo detectors arranged on both sides of an optical axis in the location [****] at the symmetry is known. The measurement result of equipment assumes the refractive power of an eye as a symmetrical thing focusing on a cornea, and an operation output is carried out by three parameters, S (the number of spherical degrees), C (astigmatism frequency), and A (whenever [astigmatism axial-angle]), so that it may double with formula values, such as a spectacle lens.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, according to this invention, eye refractive-power distribution about two or more eye refractive power and each part of a cornea in a cornea part of the direction of circles of longitude can be searched for, and a refractive-power condition can be known in a detail.
[0054] Moreover, cornea curvature distribution and refractive-power distribution can be measured with one equipment, both measurement data can be made to be able to respond, and the relation between cornea curvature and eye refractive power can be known.

[Translation done.]

* NOTICES *

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, the refractive power of an eye does not have few eyes which do not restrict but have irregular astigmatism with the symmetry focusing on a cornea, either. In an irregular astigmatism eye like the keratoconus, the measurement results of S, C, and A which are obtained when optometry-ed is looking at the core of the fixation target inside equipment, and while seeing the location which is not so differ. Therefore, it was not able to be said only with the conventional measurement data that sufficient refraction information for conducting a subjective examination efficiently was offered.
[0004] Moreover, before and after the way of this operation, although the cornea corrective surgery which corrects an ametropy by excising a cornea front face and changing cornea curvature artificially in recent years is brought into the limelight, while checking a cornea configuration in a detail, equipment which refractive-power distribution about each part of a cornea understands is desired. It is because it is how the policy objective of cornea corrective surgery brings eye refractive-power distribution close to the emmetropia (or weak degree short sight, a weak degree regular astigmatism eye).
[0005] This invention searches for refractive-power distribution of an eye by acquiring the eye refractive power in a radial cornea part and the eye refractive power of an about [each part of a cornea of many directions of circles of longitude] from which plurality differs in the one direction of circles of longitude in view of the above-mentioned conventional technique, and makes it a technical technical problem to offer the ophthalmology equipment which can know a refractive-power condition in a detail.
[0006]

MEANS

[Means for Solving the Problem] In order to solve the above-mentioned technical problem, this invention is characterized by having the following configurations.
[0008] (1) The slit projection optics which scans eyegrounds examined the eyes in the slit flux of light in the ophthalmology measuring device which measures the refractive power examined the eyes, the direction of circles of longitude corresponding to the direction of a slit of this slit flux of light -- and the cornea examined the eyes and abbreviation -- with detection optical system with two or more pairs of photo detectors arranged on both sides of an optical axis in a location [****] at the symmetry It is characterized by having a refractive-power operation means to acquire the refractive power examined [which changes in the direction of circles of longitude based on each phase contrast signal output of said photo detector] the eyes.
[0009]

EXAMPLE

[Example] One example of this invention is explained based on a drawing. Drawing 1 is the optical-system global placement Fig. of the equipment of an example. Optical system is divided roughly into an eye refractive-power measuring beam study system, fixation target optical system, the index projection optics for curvature measurement, and the index detection optical system for curvature measurement.
[0017] (Eye refractive-power measuring beam study system) The eye refractive-power measuring beam study system 100 consists of slit projection optics 1 and slit image detection optical system 10. The slit projection optics 1 has the following configurations. The source of the slit illumination light where 2 emits the light of a near-infrared region, and 3 are mirrors. 4 is the rotating sector of the shape of a cylinder rotated in the fixed direction at a fixed rate by the motor 5. Much slit opening 4a is prepared in the side face of a rotating sector 4. 6 is a projection lens and the light source 2 is located in the location [****] near the cornea examined the eyes about the projection lens 6. It is the main optical axis L1 with which 7 counters a limit diaphragm and 8 counters optometry-ed. Optical axis L2 of slit projection optics It is the beam splitter made into the same axle.
[0018] It is reflected by the mirror 3 and an infrared light which emitted the light source 2 illuminates slit opening 4a of a rotating sector 4. After the slit flux of light scanned by rotation of a rotating sector 4 passes through the projection lens 6 and the limit diaphragm 7, it is reflected by the beam splitter 8.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the ophthalmology measuring device which measures the refractive power examined the eyes.
[0002]
[Description of the Prior Art] When correcting the ametropy examined the eyes with a spectacle lens or a contact lens, the subjective examination for determining the formula value is conducted. On the occasion of a subjective examination, the method of using the measurement data of the eye refractive-power measuring device which measures the refractive power examined the eyes in other ** has spread widely. the light which scans the slit-like flux of light, projects on eyegrounds examined the eyes as an eye refractive-power measuring device, and is reflected by projection of the slit flux of light from eyegrounds examined the eyes -- the cornea examined the eyes and abbreviation -- what acquires the refractive power examined the eyes based on detecting by two pairs of photo detectors arranged on both sides of an optical axis in the location [****] at the symmetry is known. The measurement result of equipment assumes the refractive power of an eye as a symmetrical thing focusing on a cornea, and an operation output is carried out by three parameters, S (the number of spherical degrees), C (astigmatism frequency), and A (whenever [astigmatism axial-angle]), so that it may double with formula values, such as a spectacle lens.
[0003]
[Problem(s) to be Solved by the Invention] However, the refractive power of an eye does not have few eyes which do not restrict but have irregular astigmatism with the symmetry focusing on a cornea, either. In an irregular astigmatism eye like the keratoconus, the measurement results of S, C, and A which are obtained when optometry-ed is looking at the core of the fixation target inside equipment, and while seeing the location which is not so differ. Therefore, it was not able to be said only with the conventional measurement data that sufficient refraction information for conducting a subjective examination efficiently was offered.
[0004] Moreover, before and after the way of this operation, although the cornea corrective surgery which corrects an ametropy by excising a cornea front face and changing cornea curvature artificially in recent years is brought into the limelight, while checking a cornea configuration in a detail, equipment which refractive-power distribution about each part of a cornea understands is desired. It is because it is how the policy objective of cornea corrective surgery brings eye refractive-power distribution close to the emmetropia (or weak degree short sight, a weak degree regular astigmatism eye).
[0005] This invention searches for refractive-power distribution of an eye by acquiring the eye refractive power in a radial cornea part and the eye refractive power of an about [each part of a cornea of many directions of circles of longitude] from which plurality differs in the one direction of circles of longitude in view of the above-mentioned conventional technique, and makes it a technical technical problem to offer the ophthalmology equipment which can know a refractive-power condition in a detail.
[0006] Moreover, let it be a technical technical problem to offer the ophthalmology measuring device

which cornea curvature distribution and refractive-power distribution can be measured with one equipment, and both measurement data can be made to be able to respond, and can know the relation between cornea curvature and refractive power.

[0007]

[Means for Solving the Problem] In order to solve the above-mentioned technical problem, this invention is characterized by having the following configurations.

[0008] (1) The slit projection optics which scans eyegrounds examined the eyes in the slit flux of light in the ophthalmology measuring device which measures the refractive power examined the eyes, the direction of circles of longitude corresponding to the direction of a slit of this slit flux of light -- and the cornea examined the eyes and abbreviation -- with detection optical system with two or more pairs of photo detectors arranged on both sides of an optical axis in a location [****] at the symmetry It is characterized by having a refractive-power operation means to acquire the refractive power examined [which changes in the direction of circles of longitude based on each phase contrast signal output of said photo detector] the eyes.

[0009] (2) The ophthalmology measuring device of (1) has a rotation means rotate the slit flux of light further projected by said projection optics and the photo detector with which said detection optical system is equipped synchronizing with the circumference of an optical axis, respectively, and the control means which drives this rotation means at a predetermined include-angle step, and said refractive-power operation means is characterized by to acquire distribution of eye refractive power in quest of the refractive power in two or more cornea parts for a majority of every directions of circles of longitude.

[0010] (3) The ophthalmology measuring device of (2) is characterized by having a display means to display distribution of refractive power further.

[0011] (4) It is characterized by the display means of (3) being a means which carries out a graphic display.

[0012] (5) the direction of circles of longitude in which the ophthalmology measuring device of (1) does not correspond in the direction of a slit of the slit flux of light by said projection optics further -- and the reflected light from eyegrounds examined the eyes -- the cornea examined the eyes and abbreviation -- on both sides of an optical axis, it is arranged in a location [****] at the symmetry -- with the 2nd photo detector of a pair at least this -- with a main detection means to detect a cornea core or a visual-axis core based on the phase contrast signal output between the 2nd photo detector It is characterized by having a refractive-power operation means to search for refractive power based on the phase contrast signal of each of one pair of photo detectors of the location corresponding to the direction of a slit of the slit flux of light, and the detected core.

[0013] (6) The ophthalmology measuring device of (1) is characterized by having a pupil diameter measurement means to measure the pupil diameter examined the eyes based on the output signal of the photo detector of said detection optical system further.

[0014] (7) In the ophthalmology measuring device of (1), it is characterized by for said slit projection optics having a means to project the slit flux of light with whenever [at least two or more tilt-angles], and having two or more pairs of photo detectors arranged on both sides of an optical axis at the symmetry corresponding to the direction of a slit of the slit flux of light of whenever [each tilt-angle] in said detection optical system, respectively.

[0015] (8) The ophthalmology measuring device of (1) is characterized by to have the measurement mode means for switching which switches an index projection means project the index for cornea configuration measurement which has the pattern of the shape of two or more circular ring in the cornea examined the eyes further, a cornea configuration measurement means carry out detection processing of the projected index, and acquire the configuration of each field of a cornea, and the mode which measures a cornea configuration and the mode which measures eye refractive power.

[0016]

[Example] One example of this invention is explained based on a drawing. Drawing 1 is the optical-system global placement Fig. of the equipment of an example. Optical system is divided roughly into an eye refractive-power measuring beam study system, fixation target optical system, the index projection

optics for curvature measurement, and the index detection optical system for curvature measurement.
[0017] (Eye refractive-power measuring beam study system) The eye refractive-power measuring beam study system 100 consists of slit projection optics 1 and slit image detection optical system 10. The slit projection optics 1 has the following configurations. The source of the slit illumination light where 2 emits the light of a near-infrared region, and 3 are mirrors. 4 is the rotating sector of the shape of a cylinder rotated in the fixed direction at a fixed rate by the motor 5. Much slit opening 4a is prepared in the side face of a rotating sector 4. 6 is a projection lens and the light source 2 is located in the location [****] near the cornea examined the eyes about the projection lens 6. It is the main optical axis L1 with which 7 counters a limit diaphragm and 8 counters optometry-ed. Optical axis L2 of slit projection optics It is the beam splitter made into the same axle.
[0018] It is reflected by the mirror 3 and an infrared light which emitted the light source 2 illuminates slit opening 4a of a rotating sector 4. After the slit flux of light scanned by rotation of a rotating sector 4 passes through the projection lens 6 and the limit diaphragm 7, it is reflected by the beam splitter 8. Then, after penetrating the beam splitter 9 which makes the same axle the optical axis of fixation target optical system and observation optical system and condensing near the cornea examined [E] the eyes, it is projected on eyegrounds.
[0019] The slit image detection optical system 10 is the main optical axis L1. Optical axis L3 reflected by the light-receiving lens 11 and mirror 12 which were prepared upwards, and the mirror 12 It has the diaphragm 13 and light sensing portion 14 which were prepared upwards. Drawing 13 is arranged through a mirror 12 in the backside focal location of the light-receiving lens 11 (that is, located in the eyegrounds of the emmetropia examined the eyes, and a location [****]). a light sensing portion 14 is shown in the light-receiving side at drawing 2 -- as -- the light-receiving lens 11 -- being related -- the cornea examined the eyes and abbreviation -- it has eight photo detectors 15a-15h located in a location [****]. the photo detectors 15a-15f of these are located on the straight line passing through the core (optical axis L3) of a light-receiving side, and they are prepared so that photo detectors 15a and 15b, photo detectors 15c and 15d, and photo detectors 15e and 15f may become the symmetry (namely, a core [optical axis / L3] -- carrying out) to the core of a light-receiving side, respectively. That arrangement distance is set up so that three pairs of these photo detectors can detect the refractive power corresponding to each location of the direction of a path of a cornea (on drawing 2 , shown as equivalence size on a cornea). On the other hand, photo detectors 15g and 15h are opticals axis L3. It is prepared so that it may become the symmetry on the straight line which makes it a core and intersects perpendicularly with photo detectors 15a-15h.
[0020] For such an eye refractive-power measuring beam study system 100 of a configuration, the source 2 of the slit illumination light of the slit projection optics 1 - a motor 5 are an optical axis L2 by the rolling mechanism 21 which consists of a motor 20, a gear, etc. To a core, a light sensing portion 14 is an optical axis L3. It synchronizes with a core by carrying out, and rotates. And the photo detectors [on a light sensing portion 14 / 15a-15f] direction in which it is located is set up so that it may correspond to the scanning direction (the slit flux of light on eyegrounds comes to be scanned in the direction which intersects perpendicularly with the longitudinal direction of a slit) of the slit flux of light in the top examined [which is projected by the slit projection optics 1] the eyes. With the equipment of an example, when the slit flux of light by slit opening 4a is scanned on the eyegrounds of long sight or myopia without the astigmatism examined the eyes, photo detectors 15a-15f are arranged so that it may correspond in the direction which intersects perpendicularly with the longitudinal direction of the slit received on a light sensing portion 14.
[0021] (Fixation target optical system) 30 is fixation target optical system and, as for the source of the light, and 32, 31 is [a fixation target and 33] floodlighting lenses. The floodlighting lens 33 performs fog examined the eyes by moving in the direction of an optical axis. 34 is a beam splitter which makes the optical axis of observation optical system the same axle.

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[0021] (Fixation target optical system) 30 is fixation target optical system and, as for the source of the light, and 32, 31 is [a fixation target and 33] floodlighting lenses. The floodlighting lens 33 performs fog examined the eyes by moving in the direction of an optical axis. 34 is a beam splitter which makes the optical axis of observation optical system the same axle. The light source 31 illuminates a fixation target 32, after the flux of light from a fixation target 32 passes through the floodlighting lens 33 and a beam splitter 34, it is reflected by the beam splitter 9, and the optometry E-ed carries out the fixation of the fixation target 32 toward the optometry E-ed.

[0022] (Index projection optics for curvature measurement) The index projection optics 25 for curvature measurement has the next configuration. 26 is a conic PURACHIDO plate which has opening in a center section, and is an optical axis L1 in the PURACHIDO plate 26. The ring pattern which has much translucent parts and the protection-from-light sections on the concentric circle made into the core is formed. 27 is two or more sources of the illumination light, such as LED, it is reflected with a reflecting plate 28 and the illumination light emitted from the source 27 of the illumination light illuminates the PURACHIDO plate 26 to homogeneity mostly from behind. The flux of light of the ring pattern which penetrated the translucent part of the PURACHIDO plate 26 is projected on the cornea examined the eyes.
[0023] (Index detection optical system for curvature measurement) 35 is the index detection optical system for curvature measurement. The cornea reflected light bundle of the ring pattern projected by the index projection optics 25 for curvature measurement forms the cornea reflected image of a ring pattern in the image sensor side of CCD camera 38 with a taking lens 37, after being reflected by the beam splitter 9 and the beam splitter 34. Moreover, the index detection optical system for curvature measurement serves as observation optical system, image formation of the anterior eye segment image examined [which was illuminated by the source of the anterior eye segment illumination light without illustration / E] the eyes is carried out to the image sensor side of CCD camera 38 through beam splitters 9 and 34 and a taking lens 37, and the TV monitor 39 projects it.
[0024] Next, the measuring method of the eye refractive power of this invention is explained. Eye refractive-power measurement of this invention first searches for the cornea core (or visual-axis core) of the direction of circles of longitude that photo detectors 15a-15f are located from a photo detectors [15g and 15h] output signal, and searches for the refractive power in an each photo detectors [15a-15f] corresponding cornea part from the core. In order to simplify explanation, taking the case of a pair of thing of the photo detectors 15a and 15b of optical-axis approach, it explains most.
[0025] Now, the slit flux of light by slit projection optics is scanned by whenever [constant-speed], and suppose that the signal output wave in case the slit image reflected from eyegrounds crosses each photo detectors 15a, 15b, 15g, and 15h became like drawing 3 . Optometry-ed is in the condition of long sight or myopia, and this is the case where it has the astigmatism.
[0026] Now, in the eye refractive-power measurement by the phase contrast method, when refractive power assumes that it is symmetrical focusing on a cornea, it can be made to be able to respond to the phase contrast (time difference) of the wave signal from photo detector 15a of the drawing 3 (**), and the wave signal from photo detector 15b of (**), and the refractive power between photo detectors 15a and 15b can be acquired. However, refractive power is not necessarily symmetrical focusing on a cornea (or visual-axis core). Then, how to acquire the core of photo detectors 15a and 15b from a photo detectors [which are first located in the direction which intersects perpendicularly with this to photo detectors 15a and 15b / 15g and 15h] photoelectrical pressure signal is considered. If a core can be found, the refractive power in each cornea part can be searched for by acquiring the cornea equivalent location of photo detectors 15a or 15b, and the time difference based on corneas (visual-axis core).
[0027] In order to simplify explanation, when the rise time of a photoelectrical pressure signal wave generated in each photo detector in connection with the incidence of light shall be detected here (ta of drawing 3 , tb, tg, and th), it is the conventional time t0. The core of photo detectors 15a and 15b of receiving can be searched for by (tg+th) / 2. Therefore, when time amount to the cornea part corresponding to photo detector 15b for the time amount from the cornea part corresponding to photo detector 15a to a cornea core is set to Tb from Ta and a cornea core, it is Ta= [(tg+th) /2-ta].
Tb=[tb -(tg +th)/2]
The refractive power between a cornea core and a predetermined cornea part can be searched for by making a next door and this time amount Ta and Tb equivalent to refractive power.
[0028] Next, the phase contrast time amount which processes the output signal from each photo detector binary-ization, and detects it is explained. When setting up and binary--ization-processing a certain SURESSHU level to the signal outputted from each photo detector, and a quantity of light difference is between each photo detector, an error may be produced in detection of phase contrast time amount.

When the light transmission body of an eye like a cataract eye has turbidity, it is easy to produce this. For example, drawing 4 is drawing having shown the situation of the signal wave form from both components when turbidity of the cornea part corresponding to photo detector 15b is size to the cornea part corresponding to photo detector 15a (drawing has arranged the timing of light-receiving, in order to simplify explanation). wave 65 -- the signal wave form from photo detector 15a -- being shown -- a wave -- 66 shows the signal wave form from photo detector 15b. The wave amplitude of photo detector 15b is small because of turbidity. the conventional time t0 when operating orthopedically in a square wave form, when the amplitude changed although this analog wave was orthopedically operated by the wave of a square wave on a certain SURESSHU level 67 by binary-ized processing from -- the time difference of deltat will arise in each rise time ta1 and tb1. Therefore, when a quantity of light difference is between each photo detector, the time difference of deltat will turn into an error when changing into refractive power.
[0029] Then, the core (a cornea core or visual-axis core) of the direction of circles of longitude measured in consideration of the case where there is a quantity of light difference, between each photo detector, and the refractive power over the core take the time amount from the conventional time in the location of the one half of the pulse width of the pulse shape operated orthopedically, respectively. If it carries out like this, the effect of the amplitude difference in each photo detector location can be eliminated. namely, drawing 4 -- setting -- the conventional time t0 from -- what is necessary is to measure ta1 and the time amount of ta2, tb1, and tb2, and just to calculate the time amount ta3 to the core, or tb3 ta3 and tb3 are set to ta3=ta1+ta2/2tb3=tb1+tb 2/2, respectively. This means that exact time amount can be found, even if the SURESSHU level at the time of the binary-ized processing corresponding to each photo detector differs respectively.
[0030] It is drawing 5 which showed the detection approach of such time amount about each photo detector concretely. (b) shows the digital wave of the measurement pulse used as criteria, and he is trying to take the timing at the time of the start of the beginning of the pulse shape after binary-ized processing on the criteria of phase contrast time amount detection in this case among photo detectors 15a, 15b, 15g, and 15h. (**) - (**) show the digital wave acquired from its four photo detectors, and tA3, tB3, tG3, and tH3 show the time amount to the core of the pulse width from the conventional time (leading edge of a measurement pulse), respectively. When the direction of photo detectors 15a and 15b is made into the direction of measurement circles of longitude, therefore, the core (cornea core) The time difference TA in the location of photo detector 15a to the core which was searched for by (tG3+tH3) / 2, and was searched for, and time difference TB in the location of photo detector 15from core b It asks by TA =(tG3+tH3)/2-tA3TB =tB3- (tG3+tH3) / 2. And this time difference can be made to correspond to the refractive power over the core of that direction of circles of longitude.
[0031] Similarly, if a core and photo detectors [15c 15d, 15e, and 15f] refractive power are searched for, the refractive power in the cornea part corresponding to the arrangement distance of each photo detector will be acquired. And if slit projection optics and a light sensing portion 14 are synchronously rotated 180 degrees to the circumference of an optical axis, the refractive power of all the circles-of-longitude directions (360 degrees) can be searched for.
[0032] Moreover, the refractive power depending on a pupil diameter can be acquired from a cornea core by searching for the refractive power in each part applied to a periphery. On the contrary, the pupil diameter examined the eyes at the time of measurement is also measurable whether each photo detector of the direction of measurement circles of longitude received fundus-reflex light. In the case of an example, it is measurable in the equivalence size on the cornea by arrangement of the photo detectors 15a-15f shown in drawing 2 .
[0033] In addition, although three pairs of photo detectors are arranged in the example, if it arranges more than it, the refractive power in the circumference of an eye can be acquired more. Moreover, if arrangement spacing of a photo detector is made dense, the refractive power in a finer part can be acquired.
[0034] Next, actuation of equipment is explained using the outline block diagram of the signal-processing system of drawing 6 . First, measurement mode is chosen with the measurement mode

change-over switch 70. Here, the continuous measurement of keratometry and refractive-power measurement is explained.

[0035] Observing the anterior eye segment image examined [which was illuminated by the source of the illumination light (not shown) / E] the eyes with the TV monitor 39, a ** person moves equipment to four directions and order, and performs alignment (alignment projects the index for alignment on a cornea, and can use the thing of the common knowledge from which it is made for the corneal-reflex luminescent spot and reticle to become predetermined relation). If alignment is completed, a trigger signal will be generated with a measurement initiation switch without illustration, and measurement will be started.

[0036] In continuous measurement, it is started from keratometry. The source 27 of the illumination light for curvature measurement carries out predetermined time lighting, and a ring pattern with the PURACHIDO plate 26 is projected on a cornea. After the ring pattern image projected on the cornea is photoed by CCD camera 38, it is incorporated by the frame memory 71. After edge detection processing is performed by the image-processing circuit 72, as for the image captured by the frame memory 71, the processed data are memorized by memory 73 through a control circuit 50.

[0037] A control circuit 50 calculates the cornea curvature for every predetermined include angle based on the edge detection location of the memorized data. The operation of cornea curvature can be performed as follows. If detection image height when the image i by the cornea convex of the light source P which is in the optical-axis top distance D and height H from a cornea carries out image formation on a two-dimensional detection side with Lens L is made into h' and the scale factor of the optical system of equipment is set to m as shown in drawing 7 , a corneal curvature radius R can be searched for by the formula of R=(2D/H) mh' (refer to JP,7-124113,A for the detail of this operation). Moreover, the calculation approaches following in simple may be adopted. When the image height on Kj and an image pick-up side is set to hj for the proportionality constant as which the j-th ring is determined in the radius of curvature of the field projected on a cornea for the distance and the photography scale factor of the up to examined [Rj, the j-th ring height, and] the eyes, the above-mentioned relational expression is expressed as Rj=Kj-hj. Here, if Kj can be obtained for a proportionality constant as a value of an equipment proper, this is read at the time of measurement and it is made to calculate by measuring beforehand a schematic eye with two or more known curvatures which cover a measurement range, curvature distribution can be acquired extremely in a short time. In addition, about data processing of curvature measurement with continuous measurement mode, if it is made to carry out after refractive-power measurement is completed, continuous measurement can be performed efficiently.

[0038] Then, refractive-power measurement is performed. Preliminary measurement of refractive power is performed by the same approach as refractive-power measurement of the conventional phase contrast method. After moving the floodlighting lens 33 of fixation target optical system based on the refractive power acquired by preliminary measurement and putting eyegrounds examined [a fixation target 32 and / E] the eyes on a location [****], it is made for fog to start by still more suitable diopter in this measurement. From the slit projection optics 1, the slit flux of light restricted by slit opening 4a carries out incidence into an eye through a pupil, and is projected on eyegrounds. It is condensed with the light-receiving lens 11 of the slit image detection optical system 10, and the flux of light of the slit image which was reflected by eyegrounds and passed the pupil arrives on a light sensing portion 14 through diaphragm 13. Here, an optical electrical potential difference occurs in the photo detectors 15a-15h on a light sensing portion 14 at the same time the flux of light carried out incidence into the eye, when the optometry E-ed was emmetropia, but if there is an ametropy, it will move so that the light of the slit image reflected by eyegrounds may cross a light sensing portion 14 top.

[0039] From each photo detectors 15a-15h, an optical electrical potential difference is outputted with migration of the light of the slit image on a light sensing portion 14, respectively (time difference is produced on an optical electrical potential difference). Each outputted optical electrical potential difference is changed into the pulse signal in predetermined SURESSHU level made binary by the binary-ized circuits 42a-42h, after being inputted into the amplifiers 40a-40h connected to each, being

amplified and carrying out shift processing of a voltage level further in the level shift circuits 41a-41h, respectively. Then, each pulse signal is respectively inputted into counter circuits 46a-46h and OR circuit 43. OR circuit 43 is for making the start edge of the beginning in the binary-ized circuits 42a-42h into the start of a measurement pulse, and is inputted into the flip-flop 44 following a degree. Including the conventional time (start edge) used as initiation of measurement, a flip-flop 44 outputs the measurement pulse signal which means measurement time amount until it receives the Rset signal outputted from a control circuit 50 to counter circuits 46a-46d, after finishing measuring the pulse from all photo detectors.

[0040] If the pulse signal and the measurement pulse signal from a flip-flop 44 which were made binary in the binary-ized circuits 42a-42h are inputted, each counter circuits 46a-46h will count the time amount to the standup of each pulse signal to the leading edge (= conventional time) of a measurement pulse signal, and the time amount of each pulse width, and will be held. When this is explained taking the case of drawing 5 , it is the conventional time t0. The time amount to each receiving pulse signal standup is tA1 (drawing 5 tA 1= 0), tB1, tG1, and tH1 to each photo detector. Moreover, the time amount of the pulse width of a digital signal is tA2, tB2, tG2, and tH2, respectively.

[0041] The time amount which each counter circuit held is outputted by the call command signal (CSa - CSh) from a control circuit 50, and is inputted into a control circuit 50 through a data bus 47. The time amount to the standup of each pulse signal to the conventional time [in / in a control circuit 50 / each photo detector from each counter circuits 46a-46h] (tA1, tB1, tG1, tH1), After finding the time amount based on [of the direction of measurement circles of longitude (scanning direction of the slit flux of light)] corneas by the approach mentioned above based on the time amount (tA2, tB2, tG2, tH2) of pulse width, the time difference (phase contrast) in three pairs of photo detectors located in the direction of measurement circles of longitude to the core is acquired, respectively.

[0042] This will be converted into refractive power if the time difference in each cornea part in one circles of longitude is acquired. Relation like drawing 8 between the time difference and refractive power which are detected by the phase contrast method is. This relation can be sampled by, for example, using the schematic eye whose refractive-power value is known beforehand, and the refractive-power value corresponding to time difference can be acquired by making that data memorize.

[0043] Next, a motor 20 is driven and the source 2 of the slit illumination light - the motor 5, and light sensing portion 14 of the slit projection optics 1 are rotated 180 degrees to the circumference of an optical axis at a predetermined include-angle step (for example, 1 time). Based on the signal from each photo detector, the refractive power in each rotation location is acquired. These refractive-power measurement is repeated two or more times, predetermined processings (equalization, mean value, etc.) are performed and the result is memorized. Moreover, S, C, and A which are the same parameter as usual are computed by performing predetermined processing to the refractive power of each circles-of-longitude direction.

[0044] By whether each photo detector of the direction of measurement circles of longitude received fundus-reflex light at this time, since the pupil diameter examined the eyes at the time of measurement can be known, if processing which considered the condition of this and refractive-power distribution is performed, useful information can be further offered in the case of a consciousness optometry value.

[0045] The measurement data of the eye refractive-power distribution acquired as mentioned above is displayed on the display 53 for a display. Drawing 9 and drawing 10 are the example of a display. Drawing 9 displays by making refractive-power distribution when seeing from a transverse plane into a color map (or gray scale). A photo detector cannot receive fundus-reflex light by eyelashes etc., but the upper part where the color map is missing in drawing expresses the part from which refractive-power distribution was not acquired. Drawing 10 is the example which made distribution of refractive power the island three dimentional display.

[0046] In addition, although the refractive power corresponding to the cornea of three radial parts is acquired by three pairs of photo detectors in the example, this can increase the number of distribution bands and becomes easier to grasp a distribution condition by making the refractive power between the obtained cornea parts correspond to distance, and distributing it (interpolation).

[0047] Moreover, it is possible to change into cornea refractive power the radius of curvature acquired by keratometry by common knowledge ******, and to also make the distribution condition shown a graphic form table like drawing 9 or drawing 10 . Furthermore, if cornea curvature distribution (cornea refractive-power distribution: D=(n-1)/r and r= cornea curvature, effective refractive index of n= cornea) and eye refractive-power distribution are made to correspond and it is made to display on coincidence, the relation between these can be known.
[0048] in order [furthermore,] to make eye refractive-power distribution and cornea refractive-power distribution correspond -- a cornea refractive index -- a cylindrical-surface refractive-power component -- taking out -- the difference of the astigmatism component of eye refractive power, a comparison, or both -- it can display. Thereby, the condition of the residual astigmatism (difference of the total astigmatism examined the eyes and the corneal astigmatism) can be known.
[0049] Thus, by getting to know the refraction condition examined the eyes in a detail, the data which perform the treatment appropriately can be offered now also in the cornea corrective surgery which corrects an ametropy.
[0050] Moreover, since the pupil diameter examined the eyes at the time of measurement is measured by coincidence, it can use for the glasses formula in the case of consciousness optometry of this information etc.
[0051] As mentioned above, although this invention was explained based on the example, various changes are possible for this invention. For example, two or more slit openings 90a and 90b which have whenever [tilt-angle / which intersects perpendicularly] in a rotating sector 4 like <A HREF="/Tokujitu/tjitemdrw.ipdl?N0000=237&N0500=1E_N/;>?> ?77 <8///&N0001=342&N0552=9&N0553=000013" TARGET="tjitemdrw"> drawing 11 are arranged, respectively. On a light sensing portion 14, like drawing 12 , three pairs of photo detectors 91a-91f and three pairs of photo detectors 91g-91l. are arranged on the straight line which intersects perpendicularly so that it may correspond to the scanning direction of the slit openings 90a and 90b. If it does in this way, the refractive power in the cornea part corresponding to arrangement in the direction of 2 circles of longitude of the direction corresponding to two kinds of slit scanning which intersects perpendicularly of a photo detector can be found. Therefore, if a slit projection system and a light sensing portion 14 are synchronously rotated 90 degrees to the circumference of an optical axis, the refractive power of all the circles-of-longitude directions can be searched for, and the measuring time can be shortened compared with the arrangement which showed previously. Furthermore, if the number of whenever [tilt-angle / of the slit flux of light] is increased and the orientation of the photo detector on a light sensing portion 14 is increased corresponding to this, angle of rotation can be lessened and the refractive power of more directions of circles of longitude can be searched for.
[0052] Moreover, when the direction of circles of longitude does not have to be made fine, it can consider as the equipment which acquires the simple refractive-power distribution according to the number of the orientation of a photo detector, without establishing a rolling mechanism.
[0053]
[Effect of the Invention] As explained above, according to this invention, eye refractive-power distribution about two or more eye refractive power and each part of a cornea in a cornea part of the direction of circles of longitude can be searched for, and a refractive-power condition can be known in a detail.
[0054] Moreover, cornea curvature distribution and refractive-power distribution can be measured with one equipment, both measurement data can be made to be able to respond, and the relation between cornea curvature and eye refractive power can be known.

[Translation done.]

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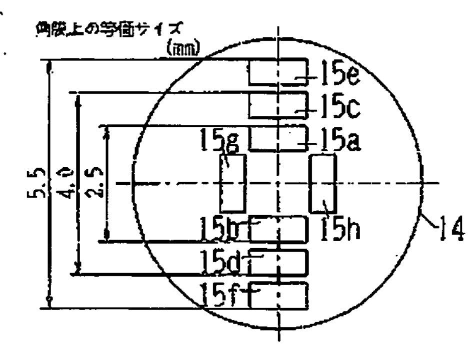
(54)【発明の名称】　眼科測定装置

(57)【要約】

【課題】　経線方向の複数の角膜部位での眼屈折力や角膜各部位での眼屈折力分布を求め、屈折力状態を詳細に知る。

【解決手段】　被検眼の屈折力を測定する眼科測定装置において、スリット光束にて被検眼眼底を走査するスリット投影光学系と、該スリット光束のスリット方向に対応した経線方向でかつ被検眼角膜と略共役な位置に光軸を挟んで対称に配置される受光素子を複数対持つ検出光学系と、前記受光素子の各々の位相差信号出力に基づいて経線方向で変化する被検眼の屈折力を得る屈折力演算手段と、を備えることを特徴とする。



【特許請求の範囲】

【請求項１】　被検眼の屈折力を測定する眼科測定装置において、スリット光束にて被検眼眼底を走査するスリット投影光学系と、該スリット光束のスリット方向に対応した経線方向でかつ被検眼角膜と略共役な位置に光軸を挟んで対称に配置される受光素子を複数対持つ検出光学系と、前記受光素子の各々の位相差信号出力に基づいて経線方向で変化する被検眼の屈折力を得る屈折力演算手段と、を備えることを特徴とする眼科測定装置。

【請求項２】　請求項１の眼科測定装置は、さらに前記投影光学系により投影されるスリット光束と前記検出光学系が備える受光素子とをそれぞれ光軸回りに同期して回転する回転手段と、該回転手段を所定の角度ステップで駆動する制御手段とを有し、前記屈折力演算手段は多数の経線方向ごとに複数の角膜部位での屈折力を求めて眼屈折力の分布を得ることを特徴とする眼科測定装置。

【請求項３】　請求項２の眼科測定装置は、さらに屈折力の分布を表示する表示手段を有することを特徴とする眼科測定装置。

【請求項４】　請求項３の表示手段は図形表示する手段であることを特徴とする眼科測定装置。

【請求項５】　請求項１の眼科測定装置は、さらに前記投影光学系によるスリット光束のスリット方向に対応しない経線方向でかつ被検眼眼底からの反射光を被検眼角膜と略共役な位置に光軸を挟んで対称に配置される少なくても一対の第２の受光素子と、該第２の受光素子間の位相差信号出力に基づいて角膜中心または視軸中心を検知する中心検知手段と、スリット光束のスリット方向に対応する位置の１対の受光素子の夫々と検出された中心との位相差信号に基づいて屈折力を求める屈折力演算手段と、を有することを特徴とする眼科測定装置。

【請求項６】　請求項１の眼科測定装置は、さらに前記検出光学系の受光素子の出力信号に基づいて被検眼の瞳孔径を計測する瞳孔径計測手段を有することを特徴とする眼科測定装置。

【請求項７】　請求項１の眼科測定装置において、前記スリット投影光学系は少なくとも２つ以上の傾斜角度を持つスリット光束を投影する手段を有し、前記検出光学系には各々の傾斜角度のスリット光束のスリット方向に対応して光軸を挟んで対称に配置される受光素子をそれぞれ複数対持つことを特徴とする眼科測定装置。

【請求項８】　請求項１の眼科測定装置は、さらに被検眼の角膜に複数の円環状のパターンを持つ角膜形状測定用指標を投影する指標投影手段と、投影された指標を検出処理して角膜の各領域の形状を得る角膜形状測定手段と、角膜形状を測定するモードと眼屈折力を測定するモードとを切換える測定モード切換手段と、を有することを特徴とする眼科測定装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、被検眼の屈折力を測定する眼科測定装置に関する。

【０００２】

【従来の技術】被検眼の屈折異常を眼鏡レンズやコンタクトレンズにより矯正するときには、その処方値を決定するための自覚検査が行われる。自覚検査に際しては、被検眼の屈折力を他覚的に測定する眼屈折力測定装置の測定データを利用する方法が広く普及している。眼屈折力測定装置としては、スリット状の光束を走査して被検眼眼底に投影し、スリット光束の投影により被検眼眼底から反射される光を被検眼角膜と略共役な位置に光軸を挟んで対称に配置された２対の受光素子により検出することに基づいて被検眼の屈折力を得るものが知られている。装置の測定結果は、眼鏡レンズ等の処方値に合わせるように、眼の屈折力を角膜中心に対称なものとして仮定し、Ｓ（球面度数）、Ｃ（乱視度数）、Ａ（乱視軸角度）の３個のパラメータにより演算出力される。

【０００３】

【発明が解決しようとする課題】しかし、眼の屈折力は角膜中心に対称とは限らず、不正乱視を持つ眼も少なくない。円錐角膜のような不正乱視眼では、被検眼が装置内部の固視標の中心を見ているときと、そうでない位置を見ているときに得られるＳ，Ｃ，Ａの測定結果は異なるものになる。したがって、従来の測定データだけでは、自覚検査を効率良く行うための十分な屈折情報を提供しているとはいえなかった。

【０００４】また、近年、角膜表面を切除したりして角膜曲率を人為的に変化させることによって屈折異常を矯正する角膜矯正手術が脚光を浴びてきているが、この手術の術前後には角膜形状を詳細に確認するとともに、角膜各部位での屈折力分布が分かる装置が望まれている。角膜矯正手術の最終目標は、眼屈折力分布をいかに正視眼（あるいは弱度近視眼、弱度正乱視眼）に近付けるかにあるからである。

【０００５】本発明は、上記従来技術に鑑み、１つの経線方向で複数の異なる半径方向の角膜部位での眼屈折力や多数の経線方向の角膜各部位での眼屈折力を得ることで眼の屈折力分布を求め、屈折力状態を詳細に知ることのできる眼科装置を提供することを技術課題とする。

【０００６】また、１台の装置で角膜曲率分布と屈折力分布とを測定し、両測定データを対応させて角膜曲率と屈折力との関係を知ることのできる眼科測定装置を提供することを技術課題とする。

【０００７】

【課題を解決するための手段】上記課題を解決するために、本発明は次のような構成を有することを特徴としている。

【０００８】（１）　被検眼の屈折力を測定する眼科測定装置において、スリット光束にて被検眼眼底を走査するスリット投影光学系と、該スリット光束のスリット方

向に対応した経線方向でかつ被検眼角膜と略共役な位置に光軸を挟んで対称に配置される受光素子を複数対持つ検出光学系と、前記受光素子の各々の位相差信号出力に基づいて経線方向で変化する被検眼の屈折力を得る屈折力演算手段と、を備えることを特徴とする。

【０００９】（２）　（１）の眼科測定装置は、さらに前記投影光学系により投影されるスリット光束と前記検出光学系が備える受光素子とをそれぞれ光軸回りに同期して回転する回転手段と、該回転手段を所定の角度ステップで駆動する制御手段とを有し、前記屈折力演算手段は多数の経線方向ごとに複数の角膜部位での屈折力を求めて眼屈折力の分布を得ることを特徴とする。

【００１０】（３）　（２）の眼科測定装置は、さらに屈折力の分布を表示する表示手段を有することを特徴とする。

【００１１】（４）　（３）の表示手段は図形表示する手段であることを特徴とする。

【００１２】（５）　（１）の眼科測定装置は、さらに前記投影光学系によるスリット光束のスリット方向に対応しない経線方向でかつ被検眼眼底からの反射光を被検眼角膜と略共役な位置に光軸を挟んで対称に配置される少なくても一対の第２の受光素子と、該第２の受光素子間の位相差信号出力に基づいて角膜中心または視軸中心を検知する中心検知手段と、スリット光束のスリット方向に対応する位置の１対の受光素子の夫々と検出された中心との位相差信号に基づいて屈折力を求める屈折力演算手段と、を有することを特徴とする。

【００１３】（６）　（１）の眼科測定装置は、さらに前記検出光学系の受光素子の出力信号に基づいて被検眼の瞳孔径を計測する瞳孔径計測手段を有することを特徴とする。

【００１４】（７）　（１）の眼科測定装置において、前記スリット投影光学系は少なくとも２つ以上の傾斜角度を持つスリット光束を投影する手段を有し、前記検出光学系には各々の傾斜角度のスリット光束のスリット方向に対応して光軸を挟んで対称に配置される受光素子をそれぞれ複数対持つことを特徴とする。

【００１５】（８）　（１）の眼科測定装置は、さらに被検眼の角膜に複数の円環状のパターンを持つ角膜形状測定用指標を投影する指標投影手段と、投影された指標を検出処理して角膜の各領域の形状を得る角膜形状測定手段と、角膜形状を測定するモードと眼屈折力を測定するモードとを切換える測定モード切換手段と、を有することを特徴とする。

【００１６】

【実施例】本発明の一実施例を図面に基づいて説明する。図１は実施例の装置の光学系概略配置図である。光学系は、眼屈折力測定光学系、固視標光学系、曲率測定用指標投影光学系、及び曲率測定用指標検出光学系に大別される。

【００１７】（眼屈折力測定光学系）眼屈折力測定光学系１００は、スリット投影光学系１とスリット像検出光学系１０から構成される。スリット投影光学系１は次のような構成を持つ。２は近赤外域の光を発するスリット照明光源、３はミラーである。４はモータ５により一定の速度で一定方向に回転される円筒状の回転セクターである。回転セクター４の側面には多数のスリット開口４ａが設けられている。６は投影レンズであり、光源２は投影レンズ６に関して被検眼角膜近傍と共役な位置に位置する。７は制限絞り、８は被検眼に対向する主光軸L_1とスリット投影光学系の光軸L_2を同軸にするビームスプリッタである。

【００１８】光源２を発した赤外の光はミラー３に反射されて回転セクター４のスリット開口４ａを照明する。回転セクター４の回転により走査されたスリット光束は、投影レンズ６、制限絞り７を経た後にビームスプリッタ８で反射される。その後、固視標光学系及び観察光学系の光軸を同軸にするビームスプリッタ９を透過して被検眼Ｅの角膜近傍で集光した後、眼底に投影される。

【００１９】スリット像検出光学系１０は、主光軸L_1上に設けられた受光レンズ１１及びミラー１２と、ミラー１２により反射される光軸L_3上に設けられた絞り１３及び受光部１４を備える。絞り１３はミラー１２を介して受光レンズ１１の後ろ側焦点位置に配置される（即ち、正視眼の被検眼眼底と共役な位置に位置する）。受光部１４はその受光面に、図２に示すように、受光レンズ１１に関して被検眼角膜と略共役な位置に位置する８個の受光素子１５ａ～１５ｈを有している。この内の受光素子１５ａ～１５ｆは受光面の中心（光軸L_3）を通る直線上に位置し、受光素子１５ａと１５ｂ、受光素子１５ｃと１５ｄ、受光素子１５ｅと１５ｆがそれぞれ受光面の中心に対して（即ち光軸L_3を中心にして）対称になるように設けられている。この３対の受光素子は、角膜の径方向の各位置に対応した屈折力を検出できるように、その配置距離が設定されている（図２上では、角膜上における等価サイズとして示している）。一方、受光素子１５ｇと１５ｈは、光軸L_3を中心にして受光素子１５ａ～１５ｈと直交する直線上で対称になるように設けられている。

【００２０】このような構成の眼屈折力測定光学系１００は、モータ２０とギヤ等から構成される回転機構２１により、スリット投影光学系１のスリット照明光源２～モータ５が光軸L_2を中心に、受光部１４が光軸L_3を中心にして同期して回転するようになっている。そして、受光部１４上の受光素子１５ａ～１５ｆの位置する方向が、スリット投影光学系１により投影される被検眼上でのスリット光束の走査方向（眼底上でのスリット光束は、あたかもスリットの長手方向に直交する方向に走査されるようになる）に対応するように設定されている。実施例の装置では、乱視を持たない遠視または近視

の被検眼眼底上でスリット開口４ａによるスリット光束が走査されたとき、受光部１４上で受光されるスリットの長手方向に直交する方向に対応するように受光素子１５ａ～１５ｆを配置している。

【００２１】（固視標光学系）３０は固視標光学系であり、３１は可視光源、３２は固視標、３３は投光レンズである。投光レンズ３３は光軸方向に移動することによって被検眼の雲霧を行う。３４は観察光学系の光軸を同軸にするビームスプリッタである。光源３１は固視標３２を照明し、固視標３２からの光束は投光レンズ３３、ビームスプリッタ３４を経た後、ビームスプリッタ９で反射して被検眼Ｅに向かい、被検眼Ｅは固視標３２を固視する。

【００２２】（曲率測定用指標投影光学系）曲率測定用指標投影光学系２５は次の構成を有する。２６は中央部に開口を持つ円錐状のプラチド板であり、プラチド板２６には光軸L1 を中心にした同心円上に多数の透光部と遮光部を持つリングパターンが形成されている。２７はＬＥＤ等の複数の照明光源であり、照明光源２７から発した照明光は反射板２８で反射され、プラチド板２６を背後からほぼ均一に照明する。プラチド板２６の透光部を透過したリングパターンの光束は被検眼角膜に投影される。

【００２３】（曲率測定用指標検出光学系）３５は曲率測定用指標検出光学系である。曲率測定用指標投影光学系２５により投影されたリングパターンの角膜反射光束は、ビームスプリッタ９及びビームスプリッタ３４で反射された後、撮影レンズ３７によりＣＣＤカメラ３８の撮像素子面にリングパターンの角膜反射像を形成する。また、曲率測定用指標検出光学系は観察光学系を兼ね、図示なき前眼部照明光源に照明された被検眼Ｅの前眼部像は、ビームスプリッタ９、３４及び撮影レンズ３７を介してＣＣＤカメラ３８の撮像素子面に結像し、ＴＶモニタ３９に映出される。

【００２４】次に、本発明の眼屈折力の測定方法について説明する。本発明の眼屈折力測定は、まず、受光素子１５ｇと１５ｈの出力信号から受光素子１５ａ～１５ｆが位置する経線方向の角膜中心（または視軸中心）を求め、その中心に対して各受光素子１５ａ～１５ｆの対応する角膜部位での屈折力を求める。説明を簡単にするために、最も光軸寄りの受光素子１５ａと１５ｂの対のものを例にとって説明する。

【００２５】いま、スリット投影光学系によるスリット光束が定速度で走査され、眼底から反射したスリット像が各受光素子１５ａ，１５ｂ，１５ｇ，１５ｈを横切るときの信号出力波形が図３のようになったとする。これは、被検眼が遠視または近視の状態でかつ乱視を持つ場合である。

【００２６】さて、位相差法による眼屈折力測定では、屈折力が角膜中心に対称であると仮定したときには、図３（イ）の受光素子１５ａからの波形信号と（ロ）の受光素子１５ｂからの波形信号との位相差（時間差）に対応させて、受光素子１５ａと１５ｂとの間の屈折力を得ることができる。しかし、屈折力は必ずしも角膜中心（または視軸中心）に対称であるとは限らない。そこで、まず、受光素子１５ａと１５ｂに対し、これと直交する方向に位置する受光素子１５ｇと１５ｈの光電圧信号から受光素子１５ａと１５ｂの中心を得る方法を考える。中心が求まれば、受光素子１５ａまたは１５ｂの角膜相当位置と角膜中心（視軸中心）との時間差を得ることで各々の角膜部位での屈折力を求めることができる。

【００２７】ここで、説明を簡単にするために、光の入射に伴って各受光素子に発生する光電圧信号波形の立上がり時間を検出するものとすると（図３のｔａ，ｔｂ，ｔｇ，ｔｈ）、基準時間ｔ0 に対する受光素子１５ａと１５ｂの中心は、

（ｔｇ＋ｔｈ）／２

で求めることができる。したがって、受光素子１５ａに対応する角膜部位から角膜中心までの時間をＴａ、角膜中心から受光素子１５ｂに対応する角膜部位までの時間をＴｂとすると、

Ｔａ＝［（ｔｇ＋ｔｈ）／２−ｔａ］

Ｔｂ＝［ｔｂ−（ｔｇ＋ｔｈ）／２］

となり、この時間Ｔａ、Ｔｂを屈折力に対応させることにより、角膜中心と所定の角膜部位間での屈折力を求めることができる。

【００２８】次に、各受光素子からの出力信号を２値化処理して検出する位相差時間について説明する。各受光素子から出力された信号に対してあるスレッシュレベルを設定して２値化処理する場合、各受光素子間に光量差があると位相差時間の検出に誤差を生じることがある。これは白内障眼のような眼の透光体に混濁がある場合等に生じやすい。例えば、図４は受光素子１５ａに対応する角膜部位に対して受光素子１５ｂに対応する角膜部位の混濁が大であったときの、両素子からの信号波形の様子を示した図である（図は説明を簡単にするために、受光のタイミングを揃えている）。波形６５が受光素子１５ａからの信号波形を示し、波形６６が受光素子１５ｂからの信号波形を示す。受光素子１５ｂの波形振幅は混濁のため小さい。このアナログ波形は２値化処理によりあるスレッシュレベル６７で矩形波の波形に整形されるが、振幅が変化すると、矩形波形に整形したときの基準時間ｔ0 からのそれぞれの立上がり時間ｔa1、ｔb1には、Δｔの時間差が生じてしまう。したがって、各受光素子間に光量差があるときには、Δｔの時間差は屈折力に変換したときの誤差となってしまう。

【００２９】そこで、各受光素子間に光量差がある場合を考慮し、測定する経線方向の中心（角膜中心または視軸中心）及びその中心に対する屈折力は、それぞれ整形されたパルス波形のパルス幅の半分の位置での基準時間

からの時間をとるようにする。こうすると、各受光素子位置における振幅差の影響を排除することができる。すなわち、図４において、基準時間$t0$からの$ta1$及び$ta2$、$tb1$及び$tb2$の時間を計測し、その中心までの時間$ta3$又は$tb3$を求めれば良い。$ta3$及び$tb3$はそれぞれ、

$ta3 = ta1 + ta2/2$

$tb3 = tb1 + tb2/2$

となる。このことは、各受光素子に対応する２値化処理のときのスレッシュレベルが各々異なっても正確な時間を求めることができることを意味している。

【００３０】このような時間の検出方法を具体的に各受光素子について示したものが図５である。（イ）は基準となる計測パルスのデジタル波形を示し、この場合は受光素子１５ａ、１５ｂ，１５ｇ，１５ｈの内、２値化処理後のパルス波形の最初の立上がり時のタイミングを位相差時間検出の基準にとるようにしている。（ロ）～（ホ）はそれ４つの受光素子から得られるデジタル波形を示し、t_{A3}、t_{B3}、t_{G3}、t_{H3}がそれぞれ基準時間（計測パルスの立上りエッジ）からのパルス幅の中心までの時間を示すものである。したがって、受光素子１５ａ、１５ｂの方向を測定経線方向としたとき、その中心（角膜中心）は、$(t_{G3}+t_{H3})/2$で求められ、求められた中心までの受光素子１５ａの位置での時間差T_A、及び中心から受光素子１５ｂの位置での時間差T_Bは、

$T_A = (t_{G3}+t_{H3})/2 - t_{A3}$

$T_B = t_{B3} - (t_{G3}+t_{H3})/2$

で求められる。そして、この時間差をその経線方向の中心に対する屈折力に対応させることができる。

【００３１】同様に、中心と受光素子１５ｃ、１５ｄ、１５ｅ、１５ｆの屈折力を求めれば、各受光素子の配置距離に対応した角膜部位での屈折力が得られる。そして、スリット投影光学系と受光部１４とを同期して光軸回りに１８０度回転させると、全経線方向（３６０度）の屈折力を求めることができる。

【００３２】また、角膜中心部から周辺部にかけての各々の部位での屈折力を求めることで、瞳孔径に依存した屈折力を得ることができる。逆に、測定経線方向の各受光素子が眼底反射光を受光したかどうかにより、測定時における被検眼の瞳孔径を計測することもできる。実施例の場合、図２に示した受光素子１５ａ～１５ｆの配置による角膜上の等価サイズで計測できる。

【００３３】なお、実施例では３対の受光素子を配置しているが、それ以上配置すれば、より眼の周辺での屈折力を得ることができる。また、受光素子の配置間隔を密にすれば、より細かい部位での屈折力を得ることができる。

【００３４】次に、装置の動作を図６の信号処理系の概略ブロック図を使用して説明する。まず、測定モード切換スイッチ７０により測定モードを選択する。ここでは、角膜曲率測定と屈折力測定の連続測定について説明する。

【００３５】検者は照明光源（図示せず）に照明された被検眼Ｅの前眼部像をＴＶモニタ３９により観察しながら装置を上下左右及び前後に移動してアライメントを行う（アライメントは位置合わせ用の指標を角膜に投影し、その角膜反射輝点とレチクルとが所定の関係になるようにする周知のものが使用できる）。アライメントが完了したら、図示なき測定開始スイッチによりトリガ信号を発生させて測定を開始する。

【００３６】連続測定では角膜曲率測定から開始される。曲率測定用の照明光源２７が所定時間点灯して、プラチド板２６によるリングパターンが角膜に投影される。角膜に投影されたリングパターン像はＣＣＤカメラ３８に撮影された後、フレームメモリ７１に取り込まれる。フレームメモリ７１に取り込まれた画像は、画像処理回路７２によりエッジ検出処理が施された後、その処理データが制御回路５０を介してメモリ７３に記憶される。

【００３７】制御回路５０は記憶されたデータのエッジ検出位置に基づき所定の角度ごとの角膜曲率を演算する。角膜曲率の演算は次のように行うことができる。図７に示すように、角膜から光軸上距離Ｄ、高さＨにある光源Ｐの角膜凸面による像ｉが、レンズＬにより２次元検出面上に結像したときの検出像高さをｈ´とし、装置の光学系の倍率をｍとすると、角膜曲率半径Ｒは、

$R = (2D/H)mh'$

の式により求めることができる（この演算の詳細は、特開平7-124113号公報を参照されたい）。また、簡易的には次のような算出方法を採用しても良い。ｊ番目のリングが角膜に投影される領域の曲率半径をR_j、ｊ番目のリング高さと被検眼までの距離及び撮影倍率で決定される比例定数をK_j、撮像面上での像高さをh_jとすると、前述の関係式は、$R_j = K_j \cdot h_j$と表される。ここで、測定レンジをカバーする複数の既知の曲率を持つ模型眼を予め測定することで、比例定数をK_jを装置固有の値として得ることができ、測定時にこれを読みだして演算するようにすると、極めて短時間で曲率分布を得ることができる。なお、連続測定モードでの曲率測定の演算処理については、屈折力測定が終了した後に行うようにすると、連続測定が効率良く行える。

【００３８】続いて、屈折力測定が実行される。従来の位相差法の屈折力測定と同様な方法により屈折力の予備測定を行う。本測定では、予備測定により得られた屈折力に基づいて固視標光学系の投光レンズ３３を移動し固視標３２と被検眼Ｅの眼底を共役な位置に置いた後、さらに適当なディオプタ分だけ雲霧がかかるようにする。スリット投影光学系１からはスリット開口４ａにより制限されたスリット光束が瞳孔を介して眼内に入射し、眼

底上に投影される。眼底で反射され瞳孔を通過したスリット像の光束は、スリット像検出光学系１０の受光レンズ１１により集光され、絞り１３を介して受光部１４上に届く。ここで、被検眼Ｅが正視眼であれば眼内に光束が入射したと同時に受光部１４上の受光素子１５ａ～１５ｈに光電圧が発生するが、屈折異常があれば眼底で反射されたスリット像の光が受光部１４上を横切るように移動する。

【００３９】受光部１４上でのスリット像の光の移動に伴い、各受光素子１５ａ～１５ｈからはそれぞれ光電圧が出力される（光電圧に時間差を生ずる）。出力された各光電圧はそれぞれに接続された増幅器４０ａ～４０ｈに入力されて増幅され、さらにレベルシフト回路４１ａ～４１ｈでそれぞれ電圧レベルのシフト処理がされた後、２値化回路４２ａ～４２ｈにより所定のスレッシュレベルでの２値化したパルス信号に変えられる。その後、各パルス信号は各々カウンタ回路４６ａ～４６ｈとＯＲ回路４３に入力される。ＯＲ回路４３は２値化回路４２ａ～４２ｈの中の最初の立上がりエッジを計測パルスの立上がりとするためであり、次に続くフリップフロップ４４に入力される。フリップフロップ４４は計測の開始となる基準時間（立上がりエッジ）を含み、全ての受光素子からのパルスを計測し終えた後に制御回路５０から出力されるRset信号を受けるまでの間の計測時間を意味する計測パルス信号をカウンタ回路４６ａ～４６ｄへ出力する。

【００４０】各カウンタ回路４６ａ～４６ｈは２値化回路４２ａ～４２ｈで２値化されたパルス信号とフリップフロップ４４からの計測パルス信号が入力されると、計測パルス信号の立上りエッジ（＝基準時間）に対するそれぞれのパルス信号の立上りまでの時間及びそれぞれのパルス幅の時間をカウントして保持する。これを図５を例にとって説明すると、基準時間ｔ０に対するそれぞれのパルス信号立上りまでの時間は、それぞれの受光素子に対して、t_{A1}（図５では$t_{A1}=0$）、t_{B1}、t_{C1}、t_{H1}である。また、デジタル信号のパルス幅の時間は、それぞれt_{A2}、t_{B2}、t_{C2}、t_{H2}である。

【００４１】各カウンタ回路が保持した時間は、制御回路５０からの呼び出し指令信号（CSa～CSh）により出力され、データバス４７を介して制御回路５０に入力される。制御回路５０は、各カウンタ回路４６ａ～４６ｈからの各受光素子における基準時間に対するそれぞれのパルス信号の立上りまでの時間（t_{A1}、t_{B1}、t_{C1}、t_{H1}）、パルス幅の時間（t_{A2}、t_{B2}、t_{C2}、t_{H2}）に基づき、前述した方法により測定経線方向（スリット光束の走査方向）の角膜中心の時間を求めた後、その中心に対して測定経線方向に位置する３対の受光素子での時間差（位相差）をそれぞれ得る。

【００４２】１経線における各角膜部位での時間差が得られたら、これを屈折力に換算する。位相差法により検出される時間差と屈折力との間には、図８のような関係がある。この関係は、例えば、予め屈折力値が既知である模型眼を使用することによってサンプリングし、そのデータを記憶させておくことにより時間差に対応した屈折力値を得ることができる。

【００４３】次に、モータ２０を駆動してスリット投影光学系１のスリット照明光源２～モータ５と受光部１４を所定の角度ステップ（例えば１度）で光軸回りに１８０度回転させる。各受光素子からの信号に基づいて各回転位置での屈折力を得る。これらの屈折力測定は複数回繰り返され、その結果は所定の処理（平均化、中間値等）が施されて記憶される。また、各経線方向の屈折力に所定の処理を施すことにより、従来と同様のパラメータであるＳ、Ｃ、Ａを算出する。

【００４４】このとき、測定経線方向の各受光素子が眼底反射光を受光したかどうかにより、測定時における被検眼の瞳孔径を知ることができるので、これと屈折力分布の状態を加味した処理を行うと、自覚検眼値の際に一層有益な情報を提供することができる。

【００４５】以上のようにして得られた眼屈折力分布の測定データは表示用ディスプレイ５３に表示される。図９、図１０はその表示例である。図９は正面から見たときの屈折力分布をカラーマップ（又はグレースケール）にして表示したものである。図においてカラーマップの欠落している上部は、瞼などにより受光素子が眼底反射光を受光できず、屈折力分布が得られなかった部分を表したものである。図１０は屈折力の分布を鳥立体表示にした例である。

【００４６】なお、実施例では３対の受光素子により半径方向の３か所の部位の角膜に対応する屈折力が得られるが、これは得られた角膜部位間の屈折力を距離に対応させて配分（補間）することにより、分布帯の数を増やすことができ、分布状態をより把握しやすくなる。

【００４７】また、角膜曲率測定により得られた曲率半径を周知な方法により角膜屈折力に変換し、その分布状態を図９や図１０のように図形表示させることも可能である。さらに、角膜曲率分布（角膜屈折力分布：$D=(n-1)/r$、ｒ＝角膜曲率、ｎ＝角膜の等価屈折率）と眼屈折力分布とを対応させて同時に表示させると、これらの間の関係を知ることができるようになる。

【００４８】またさらに、眼屈折力分布と角膜屈折力分布とを対応させるため、角膜屈折率より柱面屈折力成分を取り出し、眼屈折力の乱視成分と比較または両者の差分表示をすることができる。これにより、残余乱視（被検眼の全乱視と角膜乱視の差）の状態を知ることができる。

【００４９】このように被検眼の屈折状態を詳細に知ることにより、屈折異常を矯正する角膜矯正手術においても、その処置を適切に行うデータを提供することができるようになる。

【００５０】また、測定時における被検眼の瞳孔径が同時に計測されるので、この情報を自覚検眼の際の眼鏡処方等に役立てることができる。

【００５１】以上、本発明を実施例に基づいて説明したが、本発明は種々の変容が可能である。例えば、回転セクター４には、図１１のように、直交する傾斜角度を持つスリット開口９０ａ、９０ｂをそれぞれ複数配置する。受光部１４上には、図１２のように、３対の受光素子９１ａ～９１ｆと３対の受光素子９１ｇ～９１ｌを、スリット開口９０ａ、９０ｂの走査方向に対応するように、直交する直線上に配置する。このようにすると、直交する２種類のスリット走査に対応した方向の２経線方向での、受光素子の配置に対応した角膜部位での屈折力が求まる。したがって、スリット投影系と受光部１４とを同期して光軸回りに９０度回転させれば、全経線方向の屈折力を求めることができ、先に示した配置に比べて測定時間を短くすることができる。さらに、スリット光束の傾斜角度の数を増やし、これに対応して受光部１４上の受光素子の配置方向を増やすと、回転角度を少なくしてより多くの経線方向の屈折力を求めることができる。

【００５２】また、経線方向を細かくする必要がない場合には、回転機構を設けずに受光素子の配置方向の数に応じた簡易的な屈折力分布を得る装置とすることができる。

【００５３】

【発明の効果】以上説明したように、本発明によれば、経線方向の複数の角膜部位での眼屈折力や角膜各部位での眼屈折力分布を求めることができ、屈折力状態を詳細に知ることができる。

【００５４】また、１台の装置で角膜曲率分布と屈折力分布とを測定し、両測定データを対応させて角膜曲率と眼屈折力との関係を知ることができる。

【図面の簡単な説明】

【図１】実施例の装置の光学系概略配置を示す図である。

【図２】受光部が有する受光素子の配置を示す図である。

【図３】基準時間ｔ０に対する４個の受光素子のからの信号出力波形の例を示した図である。

【図４】受光素子１５ａに対応する角膜部位に対して受光素子１５ｂに対応する角膜部位の屈折が大であったときの、両素子からの信号波形の例を示した図である。

【図５】本発明の２値化処理の検出方法を各受光素子について示した図である。

【図６】実施例の装置の信号処理系の概略ブロック図である。

【図７】角膜曲率の演算の方法を説明する図である。

【図８】位相差法により検出される時間差と屈折力との関係を示す図である。

【図９】眼屈折力分布の測定データの表示例を示す図である。

【図１０】眼屈折力分布の測定データの別の表示例を示す図である。

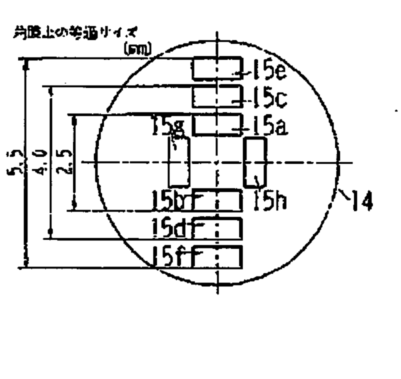
【図１１】２経線方向での測定を行う場合のスリット開口の配置例を示す図である。

【図１２】２経線方向での測定を行う場合の受光素子の配置例を示す図である。

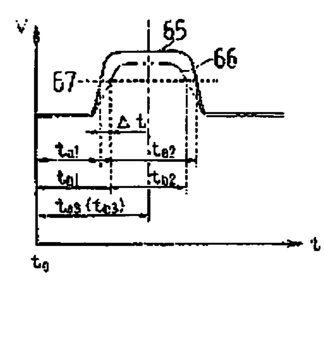
【符号の説明】

１　スリット投影光学系
４ａ　スリット開口
１０　スリット検出光学系
１５ａ～１５ｈ　受光素子
４６ａ～４６ｈ　カウンタ回路
５０　制御回路
１００　眼屈折力測定光学系

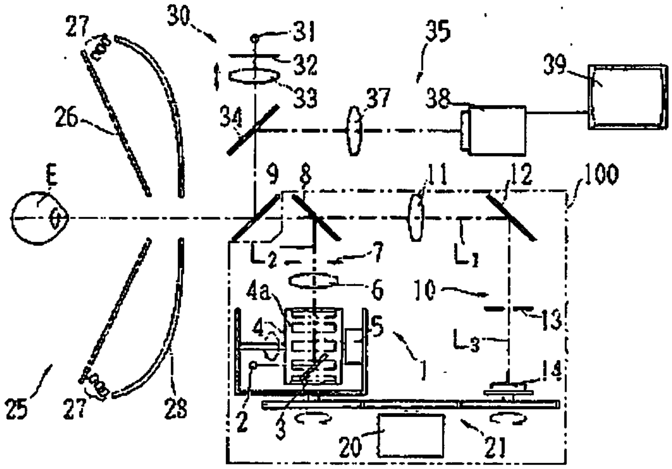
【図２】



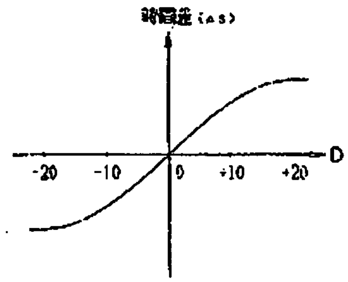
【図４】



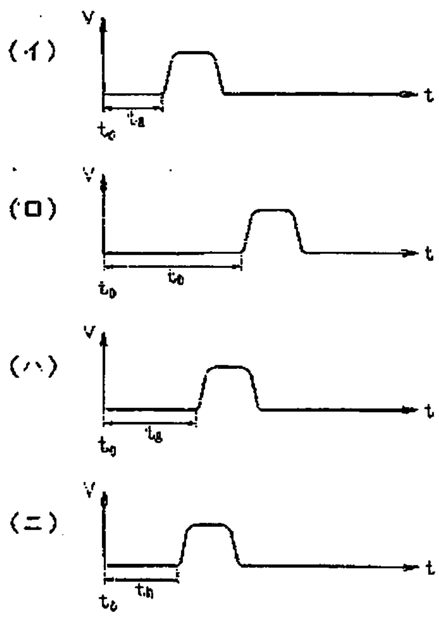
【図1】


E
L1
L2
L3

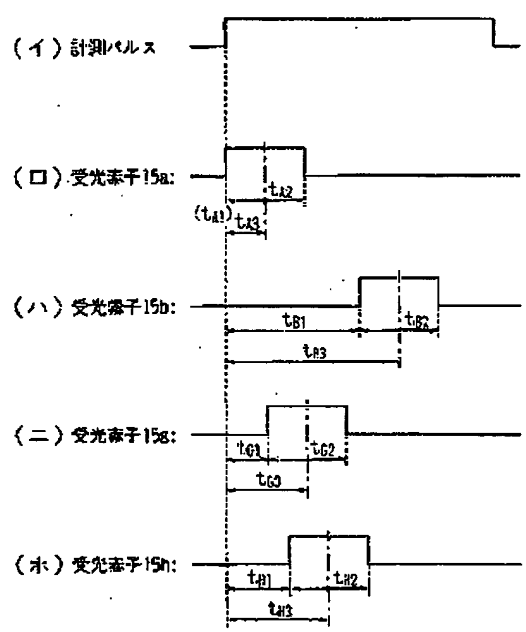
【図8】


D
-20
-10
0
+10
+20

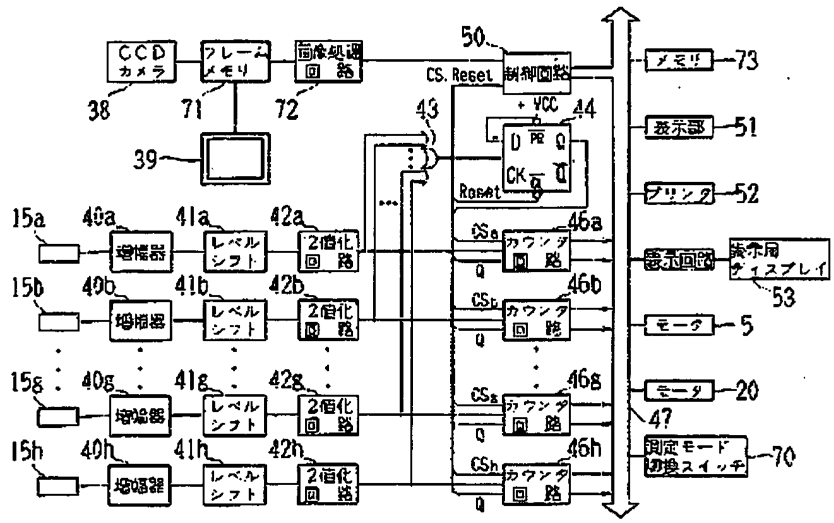
【図3】


(イ)
(ロ)
(ハ)
(ニ)
V
t

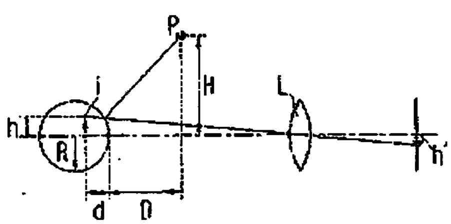
【図5】


(イ) 計測パルス
(ロ) 受光素子15a:
(ハ) 受光素子15b:
(ニ) 受光素子15g:
(ホ) 受光素子15h:

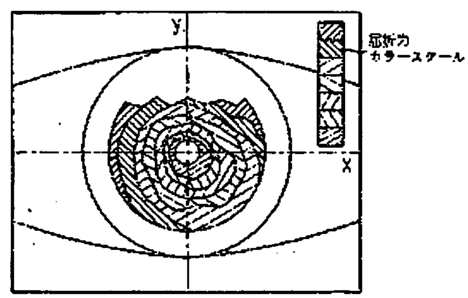
【図6】



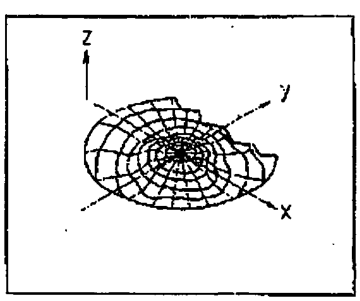
【図7】



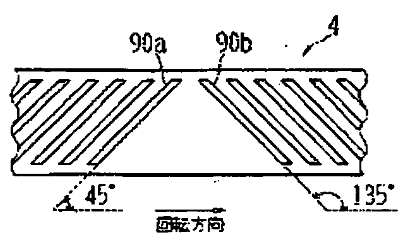
【図9】



【図10】



【図11】



【図12】